15

EXPERIMENTAL TRANSPORTATION OF LIVE SHAD PAST SUSQUEHANNA RIVER DAMS

SPECIAL SCIENTIFIC REPORT–FISHERIES No. 114

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State, or cooperating agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Douglas McKay, Secretary
Fish and Wildlife Service, John L. Farley, Director

EXPERIMENTAL TRANSPORTATION OF LIVE SHAD PAST SUSQUEHANNA RIVER DAMS

by

Charles H. Walburg
Fishery Research Biologist

Special Scientific Report: Fisheries No. 114

Washington, D. C.
January 1954

CONTENTS

FIGURE

TABLES

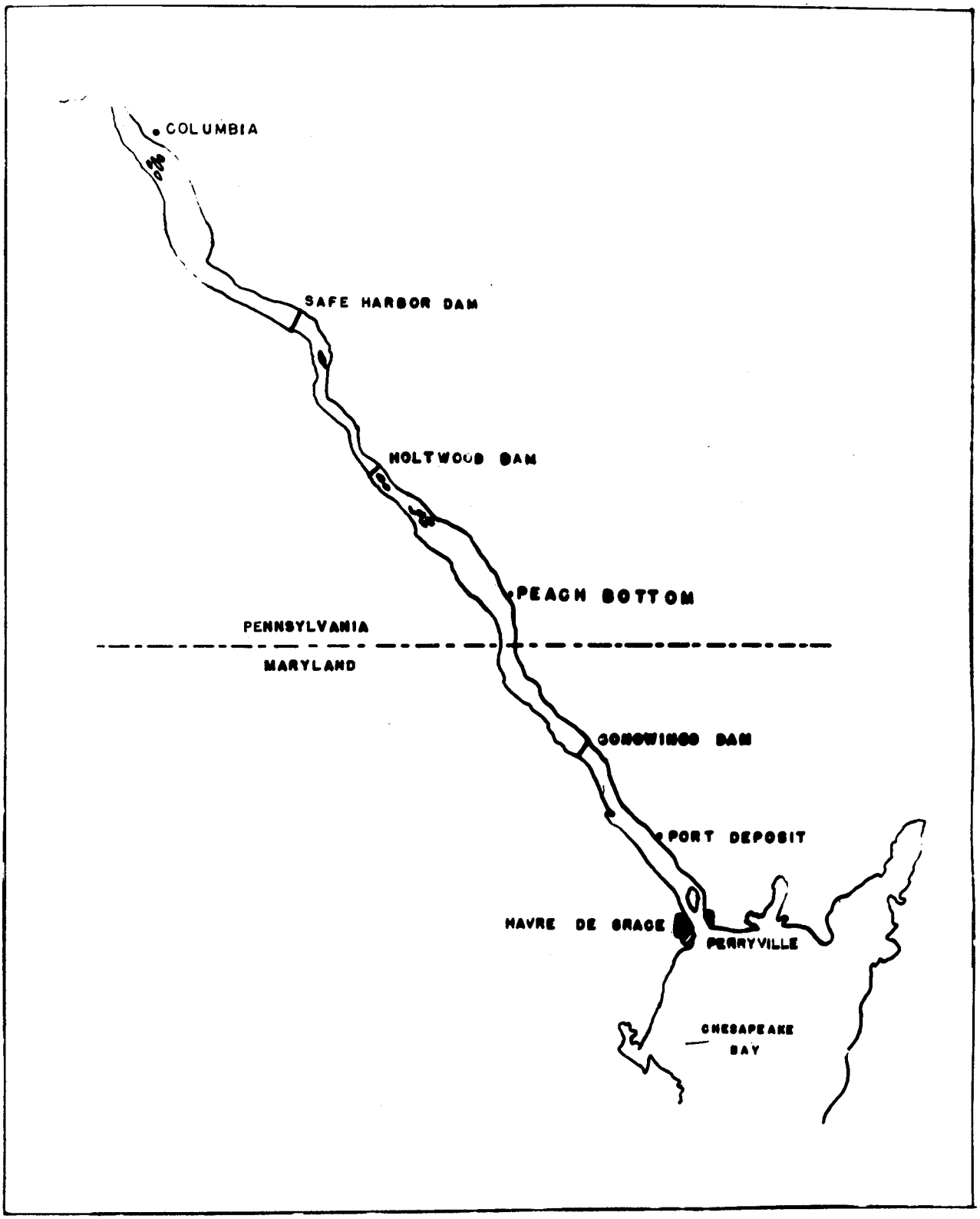
EXPERIMENTAL TRANSPORTATION OF LIVE SHAD PAST SUSQUEHANNA RIVER DAMS

The Susquehanna River has its source in Otsego Lake, New York, and flows a distance of 422 miles to its mouth at the head of Chesapeake Bay. Before the construction of dams in the 1800's, the Susquehanna River shad fishery was one of the most important on the Atlantic Coast, extending from its mouth to Binghamton, New York. The construction of many low-head dams (6 to 8 feet) in the Pennsylvania waters of the river during the 1800's greatly restricted the movement of shad (Alosa sapidissima); consequently the shad runs in these waters were greatly diminished (Stevenson, 1899).

With the advent of hydroelectric dams on the river, the upstream migration of shad has been further restricted. Holtwood Dam, 24 miles above the mouth of the river, was completed in 1910; Conowingo Dam, 10 miles above the mouth of the river, was completed in 1928; and Safe Harbor Dam, 32 miles above the mouth of the river and 8 miles above Holtwood Dam, was completed in 1932. Figure 1 shows the location of these dams on the river. Conowingo Dam presents the first obstruction to migratory fish, and because this dam is located in Maryland it prevents shad and other anadromous species from reaching the Pennsylvania waters of the Susquehanna. The height of each dam above normal tailwater elevation is as follows: Conowingo Dam, 95 feet; Holtwood Dam, 55 feet; and Safe Harbor Dam, 62 feet. If shad are to return to the waters above these dams, workable fishways will have to be installed, which by necessity must be economically justified. Before a usable fishway can be constructed, much basic biological and hydraulic information is needed.

To obtain some of this information the General Assembly of the Commonwealth of Pennsylvania in May 1951 authorized the Pennsylvania Fish Commission by Act No. 68 "to make a comprehensive study of the migratory habits of fish, particularly shad, and the stocking and tagging of shad below and above Safe Harbor Dam, the Holtwood Dam and Conowingo Dam, and to cooperate with the Federal Government and the Joint State Government Commission in connection therewith." The Fish and Wildlife Service was asked by the Joint State Government Commission to cooperate in transporting adult shad above the dams on the Susquehanna River. The purpose of this experiment, conducted in the spring of 1952, was to determine the feasibility of transporting shad for long distances and transplanting them. Information concerning the success of spawning of the transplanted shad, the survival of young, and the mortality suffered by juveniles and by adults in descending the dams was also desired.

The Pennsylvania Fish Commission provided five men and most of the equipment for the project, while the Fish and Wildlife Service furnished one man (the author) from its shad-research project to supervise the operation.


COLUMBIA
SAFE HARBOR DAM
HOLTWOOD DAM
PEACH BOTTOM
PENNSYLVANIA
MARYLAND
CONOWINGO DAM
PORT DEPOSIT
HAVRE DE GRACE
PERRYVILLE
CHESAPEAKE
BAY

Description of Transportation and Release of Shad

Adult shad were obtained from a pound net located at the mouth of the river and about 300 yards offshore near Perryville, Maryland (fig. 1). The shad were usually taken from the pound net at sunrise and placed in a live car. The live car was slowly towed to shore where the tank trucks were waiting. Each truck held four 130-gallon tanks which were filled with water taken from the bay. Each tank had a circulating system which aerated the water. Fish were taken from the live car to the truck in tubs; about 5 shad could be carried in a tub. The day's catch was divided among the available trucks.

At no time were more than 12 shad carried in each 130-gallon tank. Generally only 10 shad were placed in a tank, allowing 13 gallons of water for each fish. The lengths of the shad ranged from 17 to 21 inches, and their weights from 2 to 4 pounds. The inside dimensions of each tank were 30 x 30 x 34 inches.

When a truck was loaded, it left immediately for its destination, for time appeared to be most important in preventing mortality. There were 217 shad planted at Peach Bottom, Pennsylvania (fig. 1), 27 miles from Perryville, Maryland, where the fish were loaded; 967 shad were planted at Columbia, Pennsylvania (fig. 1), 58 miles from Perryville. Upon arrival at the stocking point the shad were removed from the tanks individually, and all but 19 were tagged with Petersen disc tags placed just below the dorsal fin, and released.

In addition to the shad hauled, 500 were tagged in the region of Havre de Grace, Maryland, at the head of Chesapeake Bay. This latter group served as the control lot with which to compare survival of the shad transported above the dams.

Effect of Hauling on Survival

Originally this experiment called for 2,000 tagged shad to be placed above Safe Harbor Dam, 500 above Holtwood Dam, and 500 above Conowingo Dam, and 1,000 to be tagged and returned to the region of the Susquehanna Flats or the head of the bay. Heavy rainfall over the Susquehanna River watershed during the spring of 1952 greatly hampered operations. The pound net from which the shad were obtained could be fished only at times of normal flow, and was removed when the river was in flood stage. As a result there was only about 1 month of effective pound-net fishing. The experiment came to an abrupt halt on May 26, when a heavy rain returned the river to flood stage and the net was removed for the season.

Tables 1 and 2 contain the complete daily record of all hauls made. Shad hauled to Peach Bottom survived much better than those hauled 31 miles further to Columbia. From table 1 it will be noted that 89 percent of the shad hauled to Peach Bottom survived the journey. Breaking

Table 1.--Daily record of shad hauled from Perryville, Md., to Peach Bottom, Pa.

(Hauling distance, 27 miles. Temperature in degrees Fahrenheit.)

Date	Temperature loading point	Start of trip: Time	Start of trip: Water temperature in tanks	End of trip: Time	End of trip: Water temperature in tanks	Water temperature stocking point	Number of Females: Hauled	Number of Females: Survived	Number of Males: Hauled	Number of Males: Survived
1952										
Apr 24	--	7:00 p.m.	—	8:00 p.m.	--	--	--	*4	--	*4
May 1	54	8:30 a.m.	54	9:35 a.m.	53	—	4	4	10	10
2	54	8:20 a.m.	55	9:20 a.m.	55	—	10	8	15	13
5	59	8:20 a.m.	58	9:20 a.m.	58	--	18	14	19	15
6	57	8:30 a.m.	57	9:30 a.m.	56	58	6	6	14	14
6	57	8:30 a.m.	57	9:30 a.m.	56	58	8	6	12	12
6	57	8:30 a.m.	57	9:30 a.m.	56	58	7	7	14	14
7	59	7:30 a.m.	59	8:30 a.m.	58	58	32	31	0	0
7	59	8:00 a.m.	59	9:00 a.m.	58	58	31	20	0	0
7	59	8:30 a.m.	59	9:30 a.m.	58	58	0	0	35	35
						Total	116	96**	119	113**
						Survival by sexes		83%		95%
						Survival, both sexes				89%

* Not used in analysis because the fish were held in a live car 10 hours before being planted and were in very poor condition.

** Excluding Apr. 4 haul.

Table 2.--Daily record of shad hauled from Perryville, Md., to Columbia, Pa.

(Hauling distance, 58 miles. Temperature in degrees Fahrenheit.)

Date	Temperature loading point	Start of trip: Time	Start of trip: Water temperature in tanks	End of trip: Time	End of trip: Water temperature in tanks	Water temperature stocking point	Number of Females: Hauled	Number of Females: Survived	Number of Males: Hauled	Number of Males: Survived
1952										
May 3	56	7:30 a.m.	56	9:15 a.m.	52	—	10	6	14	11
8	57	7:30 a.m.	58	9:15 a.m.	58	58	29	23	3	3
	57	8:00 a.m.	58	9:45 a.m.	58	58	28	11	4	4
	57	8:30 a.m.	58	10:15 a.m.	58	58	0	0	43	29
9	58	8:15 a.m.	56	9:45 a.m.	57	60	7	6	26	25
	58	8:30 a.m.	56	10:00 a.m.	57	60	6	2	27	21
	58	8:45 a.m.	56	10:15 a.m.	57	60	7	4	21	15
10	59	9:00 a.m.	60	10:45 a.m.	62	62	2	1	29	24
	59	9:15 a.m.	61	11:00 a.m.	62	62	4	1	28	20
	59	9:30 a.m.	62	11:30 a.m.	63	62	2	2	28	25
13	59	8:30 a.m.	57	10:15 a.m.	56	—	4	3	17	14
14	59	8:05 a.m.	58	9:45 a.m.	58	54	4	3	36	27
	59	8:30 a.m.	58	10:30 a.m.	58	54	5	1	35	17
	59	8:30 a.m.	58	10:30 a.m.	58	54	2	0	30	22
15*	59	9:15 a.m.	58	11:15 a.m.	58	58	19	1	21	6
	59	9:15 a.m.	58	11:15 a.m.	59	58	26	4	15	3
16	55	9:00 a.m.	56	10:30 a.m.	57	57	2	2	17	15
	55	9:15 a.m.	56	11:00 a.m.	58	57	7	6	12	11
	55	9:15 a.m.	56	11:00 a.m.	58	57	8	5	15	11
17	58	9:00 a.m.	58	10:30 a.m.	57	58	8	7	15	12
	58	9:15 a.m.	58	11:00 a.m.	57	58	5	2	17	12
19	57	8:45 a.m.	57	10:15 a.m.	57	58	13	6	27	23
	57	9:00 a.m.	57	10:45 a.m.	58	58	16	6	22	16
	57	9:00 a.m.	57	10:45 a.m.	58	58	11	4	28	23
20	58	9:15 a.m.	57	11:00 a.m.	56	57	16	8	24	20
	58	9:30 a.m.	57	11:30 a.m.	56	57	3	0	28	21
	58	9:30 a.m.	57	11:30 a.m.	56	57	7	1	14	10
21***	57	9:15 a.m.	57	10:45 a.m.	58	58	5	4	35	30
	57	9:30 a.m.	53	11:15 a.m.	52	58**	5	5	27	23
	57	9:30 a.m.	57	11:15 a.m.	60	58	4	2	41	34
22	58	9:00 a.m.	57	10:45 a.m.	59	58	6	3	34	32
	58	9:30 a.m.	56	11:15 a.m.	52	58**	8	5	32	26
	58	9:30 a.m.	57	11:15 a.m.	60	58	10	7	34	29
23	58	9:15 a.m.	58	11:00 a.m.	61	60	3	3	40	36
	58	9:30 a.m.	58	11:15 a.m.	61	60	6	3	40	30
24	58	9:15 a.m.	59	10:45 a.m.	60	60	5	4	35	24
	58	9:45 a.m.	59	11:15 a.m.	60	60	6	2	32	21
	58	9:45 a.m.	59	11:15 a.m.	60	60	7	2	34	28
26	60	9:45 a.m.	61	11:15 a.m.	63	59	12	5	36	21
	60	10:00 a.m.	61	11:30 a.m.	64	59	19	5	28	19
	60	10:00 a.m.	61	11:30 a.m.	63	59	15	3	26	6
					Total		362	168	1070	799
					Survival by sexes			46%		75%
					Survival, both sexes					68%

* Fish were in poor condition when removed from pound net.
** 300 pounds of ice used to reduce water temperature.
*** 19 of the shad hauled on this date were not tagged.

this down by sexes, 83 percent of the females and 95 percent of the males survived. Table 2 shows that only 68 percent of the shad carried to Columbia survived the trip. The females had a 46-percent survival and the males a 75-percent survival. The increased hauling distance exerted a greater effect on the mortality of the females than on that of the males.

Disregarding the haul made April 24, 1,667 shad were hauled, of which 1,176 survived to be planted at the two locations. This represents a 71-percent survival, which was influenced by the high survival rate of the males. We intended to stock an equal number of males and females, but during the 1952 shad-fishing season the net caught a higher proportion of males. As a result, 478 females and 1,189 males were hauled. Had an equal number of both sexes been available, we probably would have obtained a lower survival rate.

We have observed that shad confined in large tanks appear to carry on normal respiration by swimming with the gill covers extended. Under certain conditions of confinement the shad will obtain oxygen by pumping water through its gills like many other species of fish. The hauling tanks used in this experiment were too small to allow for normal respiratory movement and therefore the shad had to respire by pumping water through their gills.

The shad were often in distress by the time we reached the stocking point. This was especially true of those that were carried to Columbia, Pennsylvania, where mortality after hauling was greatest. Sykes (1951) transported adult shad in a larger tank for a greater distance, and obtained a higher survival rate than obtained in this experiment. The better survival rates reported by Sykes were probably due to the fact that a larger hauling tank was used. We believe that adult shad could be hauled more successfully in a hauling tank that would allow the shad to respire normally. This could be accomplished by using a tank in which the water could be circulated to form a current. The shad could then orient themselves in this current and respire normally. Another possibility is a large elliptical tank in which the shad could swim around its perimeter. This would eliminate the necessity of creating a current.

No significant correlation could be found between the temperature in the hauling tanks and the survival rate upon arrival at either of the two stocking locations.

Recoveries of Shad Planted Above the Dams

The total number of tags returned from the shad planted above the dams is shown in table 3. Of the 217 shad planted above Conowingo Dam, 40 (25 males and 15 females) were recovered alive in the 1952 commercial fishery at the head of Chesapeake Bay. There were 27 live shad (24 males and 3 females) recovered from the 948 planted above Safe Harbor Dam. All except one of these were taken by the commercial fishery in Maryland. It is

Table 3.--Total number of tags returned from shad planted above dams

Above Conowingo					Above Safe Harbor				
Date Planted	Number Planted	Number Returns Dead	Number Returns Alive	Percent Retaken Alive	Date Planted	Number Planted	Number Returns Dead	Number Returns Alive	Percent Retaken Alive
1952					1952				
Apr 24	8	0	0	0	May 3	17	0	0	0
May 1	14	1	0	0	8	70	1	0	0
2	21	1	2	9.5	9	73	3	4	5.5
5	29	0	9	31.0	10	73	2	4	5.5
6	59	0	7	11.9	13	17	0	0	0
7	86	1	22	25.6	14	70	0	3	4.3
					15	14	0	0	0
					16	50	1	1	2.0
					17	33	1	1	3.0
					19	78	0	1	1.3
					20	60	0	2	3.3
					21*	79	0	2	2.5
					22	102	1	5	4.9
					23	72	1	3	4.2
					24	81	0	1	1.2
					26	59	1	0	0
Total	217	3	40		Total	948	11	27	

* There were 19 untagged shad planted which are not included in this table.

believed that most of these shad passed through the floodgates of the dams during periods of high water. Both Conowingo and Safe Harbor Dams have floodgates, but at Holtwood Dam there are no floodgates and the excess water spills over the crest of the dam. Table 4 shows the schedule of gate operations.

The relation between the percentage survival after hauling and the percentage recaptured from each planting was determined for the shad planted above Conowingo Dam. There was no correlation between these factors, so it can be assumed that mortality subsequent to hauling was not directly related to mortality during hauling. This relation could not be tested for the shad planted at Columbia because the fishing rate was not uniform during the period these fish were susceptible to capture.

Fourteen dead shad were recovered during the course of the experiment. Of these, 7 were found below Conowingo, 1 below Holtwood, 2 below Safe Harbor, and 4 at Columbia, Pennsylvania, the stocking site above Safe Harbor. Most of the dead shad found below the dams had suffered injuries, such as bruises, cuts, and gashes. These injuries were probably incurred in passing through trash racks and turbines or in passing over the spillway and hitting the rocks below. The fact that most of the dead shad were picked up below Conowingo Dam may be accounted for by the greater height of the dam and the greater boat and fishing activity there.

That shad were able to descend the dams and live has been demonstrated. To determine whether any shad actually passed through the turbines of the dams and survived, it is necessary to review the recoveries from plantings made during the times when no floodgates were open at Conowingo and/or Safe Harbor Dams. Table 4 gives the dates when no floodgates were open. From May 5 to 11 inclusive, no floodgates were open at Conowingo Dam. Of 29 shad released above Conowingo Dam on May 5, two were recaptured alive. One was taken on May 8 at Havre de Grace, Maryland, and the other was taken on May 10 off Worton Point, Maryland. Two shad planted above Conowingo on May 7 were recaptured on May 10, one at Perryville, Maryland, and the other at Port Deposit, Maryland. One shad planted May 7 above Conowingo Dam was found dead below the dam on May 11; it was probably killed while passing through a turbine. From May 2 to 12 inclusive, no floodgates were open at Safe Harbor Dam. One shad planted May 9 above Safe Harbor was recaptured May 11 by an angler between Safe Harbor and Holtwood Dams. It is evident that at least a few shad were successful in passing through the turbines of the Safe Harbor and Conowingo Dams. No information could be found concerning the passage of shad through the turbines at Holtwood Dam because water was spilling over the crest of the dam during the entire time the experiment was in progress.

Each dam has bar-type trash racks mounted at the entrance to the water intake of the turbines. The spaces between the bars on the racks of each dam are as follows: Conowingo, 5 1/2 inches; Holtwood, some units 2 inches and others 4 inches; Safe Harbor, 6 3/8 inches. To pass through a turbine, a shad must first pass between the bars of the trash racks. It is likely that a shad has much less chance of passing through the Holtwood trash racks than the racks on the other two dams.

Table 4.--Number of floodgates open on Conowingo and Safe Harbor Dams during experiment

(Floodgates on Safe Harbor Dam are larger than those on Conowingo Dam. Decimal denotes fraction that one gate was open.)

Date	Conowingo	Safe Harbor
1952		
Apr 20	3.0	--
21	2.0	--
22	1.5	--
23	1.0	--
24	1.0	--
25	1.5	--
26	1.5	--
27	2.5	--
28	5.0	--
29	5.0	--
30	3.0	--
May 1	2.0	0.25
2	1.0	0.00
3	1.0	0.00
4	1.0	0.00
5	0.0	0.00
6	0.0	0.00
7	0.0	0.00
8	0.0	0.00
9	0.0	0.00
10	0.0	0.00
11	0.0	0.00
12	1.5	0.00
13	2.0	0.66
May 14	3.0	0.66
15	3.0	1.00
16	2.5	0.50
17	1.5	0.25
18	1.0	0.00
19	1.0	0.00
20	1.0	0.00
21	1.0	0.00
22	1.0	0.00
23	1.5	0.66
24	2.5	0.50
25	2.0	0.25
26	3.5	1.00
27	7.5	3.50
28	8.0	3.50
29	5.0	1.75
30	3.0	0.75
31	2.0	0.25
June 1	1.5	0.00
2	0.75	0.00
3	1.0	0.00
4	0.0	0.00
5	0.0	0.00

Soon after the first of June, the rainfall over the Susquehanna watershed returned to normal, and the floodgates on both Safe Harbor and Conowingo Dams remained closed. During July of 1952 we received reports of dead shad above the dams. J. S. Wertz of Washington Boro, Pennsylvania, reported 25 dead shad between Columbia, Pennsylvania, and Safe Harbor Dam. John Ogden, Fish Warden, Pennsylvania Fish Commission, reported 15 dead shad below Holtwood Dam. These reports lead us to believe that a large number of the planted shad died between Columbia and Conowingo Dams.

Sampling for Juvenile Shad Produced Above Dams

We sampled for juvenile shad above the dams in August with a small trawl and a 20-foot seine, but none were taken. In September and October, attempts were made to intercept downrunning juvenile shad by placing a small net in the tailrace of Conowingo Dam. No juveniles were found at this time either. With the limited spawning population available above the dams, the probability of finding even one juvenile shad was extremely low with the sampling devices available. During the 1951 Hudson River juvenile-sampling program, when the spawning population consisted of approximately 156,000 fish 1/, we were able to obtain only a few hundred young shad. Therefore, the failure to find any young does not necessarily indicate a failure of the adults to spawn above the dams.

Comparison of Recoveries of Shad Planted Above Dams with Control Lot

Of the 500 fish tagged at the head of the bay during the 1952 shad-fishing season, 258 were recaptured by the commercial fishermen in the area. This represents an estimated fishing rate of 51.6 percent. The number of tagged fish that escaped the fishery was 242. These fish were available to the fishery in 1953 provided they underwent no mortality and no tag loss occurred.

Of the fish planted at Peach Bottom, 40 were recovered in the commercial fishery below Conowingo Dam. These recaptures were made over the same general period of time as were the recaptures from those tagged at the head of the bay. Therefore, both groups were subjected to the same fishing rate.

The estimated number of shad released above Conowingo that descended to the head of the bay is 40 ÷ 0.516, or 77 fish. Since 40 of the 77 fish were recaptured by the fishery, 37 were free to leave the area and return in 1953, provided they underwent no further mortality and no tags were lost.

1/ Progress Report, 1951 Shad Investigation Program, U. S. Fish and Wildlife Service, Beaufort, N. C. 5 pp. (Duplicated)

During the 1953 shad-fishing season, we canvassed the fishery at the head of the bay for tag returns from the two groups of shad. The following table gives the recovery data.

	Recovered	Not recovered	Total
Head of bay population	6	236	242
Conowingo	1	36	37
Total	7	272	279

$$X^2 = 0.2337,\ 1\ d.f.,\ P \sim 0.65$$

A chi-square analysis reveals no significant difference in the proportion of recaptures for the two groups of tagged shad. The inferences are these: (1) There was no difference in the survival rate between shad that were planted at Peach Bottom, Pennsylvania, and descended Conowingo Dam, and those that were tagged at the head of the bay; hence, the shad that descended the dam suffered no lasting ill effects; (2) the estimate of the number of shad that descended Conowingo Dam and lived appears to be fairly accurate.

Of the 967 shad planted at Columbia, Pennsylvania, 26 were recaptured in Maryland between the time of planting and June 5, 1952, when the fishing season ended. These 26 shad were subjected to a fishing rate less than 51.6 percent since they were recaptured near the end of the fishing season. If this group of shad had been subjected to a fishing rate of 51.6 percent, an estimated 50 shad from this group would have descended the three dams. Since the fishing rate was less than 51.6 percent during the period of recapture, probably more than 50 shad descended all three dams. We obtained no tag returns from this group in 1953, so we can assume that not many more than 50 shad from this planting descended the dams. If there had been, we should have expected tag returns in the approximate ratio of 1:40 as observed in the other areas.

The 242 tagged shad at the head of the bay that escaped the fishery in 1952 must have suffered a high natural mortality or a considerable loss of tags, since only 6 of these fish were recaptured during the 1953 shad season. Some of the natural mortality was probably due to deaths following spawning. The shad that remained above the dams probably experienced a similar mortality after spawning. Those that survived probably had difficulty in locating the turbine intakes or would not enter them. Eventually, warm water and lack of food meant likely death for those shad that did not descend the dams.

Summary

1. During the spring of 1952, 1,184 adult shad were transported from the head of Chesapeake Bay near Perryville, Maryland, to stocking locations above Conowingo and Safe Harbor Dams on the Susquehanna River. All but 19 fish were tagged before release.

2. Five hundred shad were tagged and released at the head of Chesapeake Bay to serve as a control.

3. Of the shad planted above Conowingo Dam, 89 percent survived to point of planting, while of those planted above Safe Harbor Dam, only 68 percent survived. Thus the survival rate of the shad decreased as the hauling distance increased.

4. We believe that a higher survival rate would have been obtained if the hauling tanks had been larger and arranged so that the shad could swim and respire in a normal manner.

5. Forty of the tagged shad were retaken by the commercial fishery in Maryland.

6. Most of the shad that descended the dams probably came through the floodgates.

7. Authentic reports indicate that a large number of the planted shad died above the dams.

8. Attempts were made to locate juvenile shad in order to determine the success of spawning of the planted shad, but none were found.

9. From tag recoveries it was determined that 51.6 percent of the shad present were taken by the commercial fishery during the 1952 shad season and that 77 of the planted shad passed downstream over Conowingo Dam. There was no significant difference between the survival rate of the shad planted above Conowingo Dam and that for the shad tagged at the head of Chesapeake Bay.

10. It was estimated that somewhat more than 50 of the 967 shad planted at Columbia, Pennsylvania, successfully passed downstream over Safe Harbor, Holtwood, and Conowingo dams.

LITERATURE CITED

Stevenson, Charles H.

1899. The shad fisheries of the Atlantic Coast of the United States. Part XXIV, Report of the U. S. Commissioner of Fish and Fisheries for 1898, pp. 224-227.

Sykes, James E.

1951. The transfer of adult shad. Progressive Fish-Culturist, Vol. 13, No. 1 (January 1951), pp. 45-46.